Energy & Materials Resource Flows

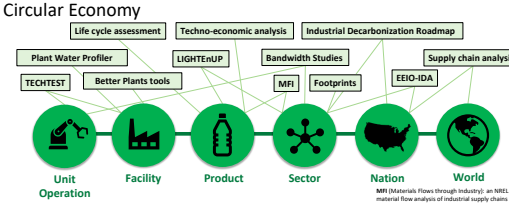
Presenter: Kristina Armstrong (ORNL)
Authors: Alberta Carpenter (NREL), Kenta Shimizu (Energetics), Kristina Armstrong (ORNL), Samantha Reese (NREL), Heather Liddell (Energetics), and Sachin Nimbalkar (ORNL)
IEDO/AMMTO Strategic Analysis Team Led by Joe Cresko (DOE IEDO)

AMMTO & IEDO JOINT PEER REVIEW
May 16th-18th, 2023
Washington, D.C.

This poster does not contain any proprietary, confidential, or otherwise restricted information

Abstract

This poster presents on flows of resources that support manufacturing, including flows of energy and materials. It highlights the recent and current strategic analysis efforts such as energy & carbon footprints, case studies showing the interconnectedness between sectors and global perspective & competitiveness, NREL's Materials Flows through Industry (MFI) tool; and our big impact report on Sustainable Manufacturing and Circular Economy



There are three things we always need to know to understand impact:
1.) **What** are (collective) anticipated impacts; e.g. energy, emissions
2.) **Where** will (collective) impacts occur; e.g. sector(s)/end-use(s)
3.) **When** will impacts occur; e.g. time period, penetration uptake

MFI (Materials Flows through Industry): an NREL tool for environmental and material flow analysis of industrial supply chains

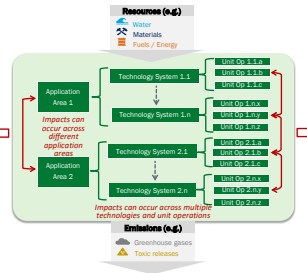
EEIO-IDA (Environmentally Extended Input/Output for Industrial Decarbonization Analysis): an IEDO-developed model for analysis of emissions accrual through industry supply chains

TECHTEST (Techno-economic, Energy, and Carbon Heuristic Tool for Early Stage Technologies): an IEDO/AMMTO-developed Excel tool for simplified life cycle assessment (LCA) and techneconomic analysis (TEA) of low-TRL technologies

LIGHTENUP (Lifecycle Industry GreenHouse gas, Technology, and Energy through the Use Phase): an LBL developed tool for forecasting product and sector life-cycle energy and emissions across the US economy

Flows at the Unit Operations & Facility Level

In aggregate, individual mass/energy balances at the unit operation level generate environmental impacts across the U.S. economy



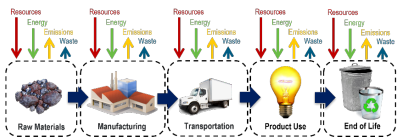
Decarbonization of the Economy

Life-Cycle Targets
- Product life cycle emissions and energy use
- Life cycle resource consumption of industrial products
- Circularity

Decarbonization of the Industrial Sector

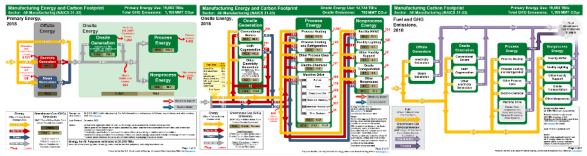
Process-Level Targets
- Manufacturing energy and process emissions
- Industrial energy efficiency
- Facility resource utilization

Flows at the Product & Sector Level



Life cycle approaches are essential for accurate accounting of embodied energy & emissions in manufactured goods

Onsite and offsite energy use and GHG emissions | Only onsite energy use and GHG emissions | Carbon-centric onsite and offsite fuel use and GHG emissions



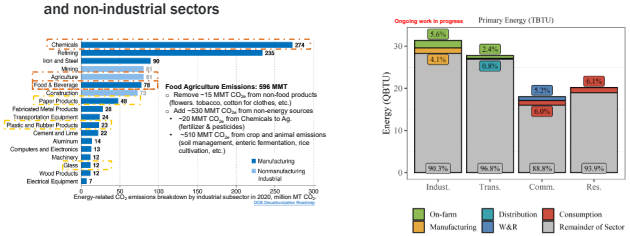
https://www.energy.gov/eere/amo/manufacturing-energy-and-carbon-footprints-2018-mecs

The footprints can help address: Which manufacturing sectors have the highest GHG emissions? What are the key energy sources for these sectors? Which cross-cutting processes consume the most energy? Where are the greatest energy losses incurred?

Interconnectedness Between Sectors

Case Study: U.S. Food Supply Chain

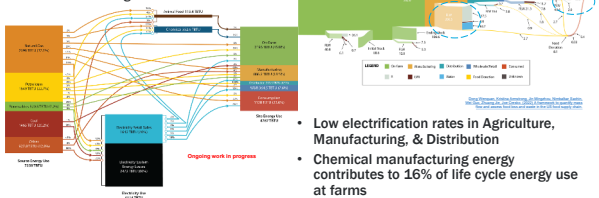
Covers highly diverse food & beverage products that incorporate several industrial and non-industrial sectors



Relevant expertise/ tools in our suite: life cycle assessment, techno-economic analysis, MFI Tool, spatial analysis and optimization

Key challenge to FSC decarbonization – Material waste

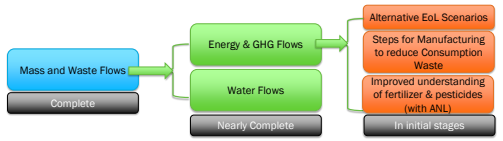
- Material waste is a key challenge to decarbonizing the FSC
- Manufacturing waste is "remanufactured" for other products instead of other primary materials
- Consumer waste goes to landfills

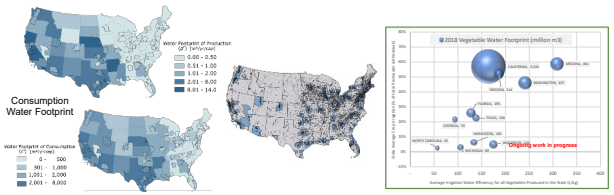


- Low electrification rates in Agriculture, Manufacturing, & Distribution
- Chemical manufacturing energy contributes to 16% of life cycle energy use at farms

Additional Ongoing Efforts related to the Food Supply Chain

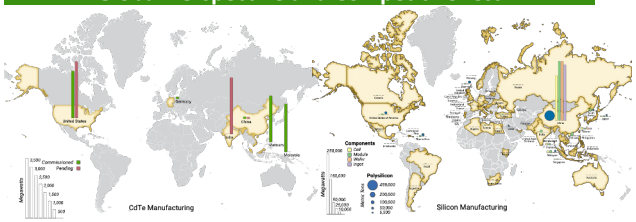
ORNL Food Supply Chain Work (FY24)
Growing and connecting with more areas





Controlled Environment Agriculture (NREL):
- Most veggies are grown in water stressed areas (Western US)
- Moving production away from these regions would be greatly beneficial
- Exploring tradeoffs of current system vs CE agriculture (vertical farms) – Energy vs. water use **with geographic component**

Global Perspective and Competitiveness

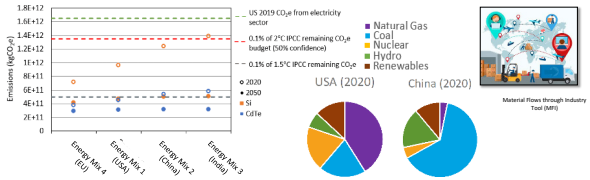


CdTe is 40% of the U.S. axis-based tracking market, and ~25% of cumulative U.S. installations >1 MW.

Silicon based solar cells are most dominant, 90%+ of global market.

Worldwide Industrial GHG Contributors

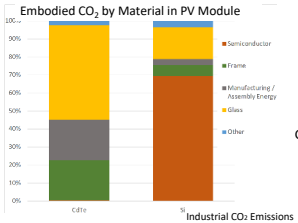
Case Study: Reaching Renewable Deployment Goals - Photovoltaics Embodied Carbon for 1 TW



- Each energy mix has ~25% difference as you step up
- US manufactured CdTe vs China manufactured SI mitigates over 786Mt CO_2e
- **2%–14%** of the remaining estimated IPCC carbon budget might be consumed for manufacturing PV modules
- In 2023 PV could contribute 2% of the World's industrial emissions

Source	% Industrial GHG Contribution Per Year
Ferrous and non-ferrous metals	14.3%
Chemicals	10.1%
Cement*	8.8%
231 GW PV in 2023 (Assume SI & China 2020)	1.9%
57 TW PV in 2050, assuming 2TW a year (SI & China 2020)	16%

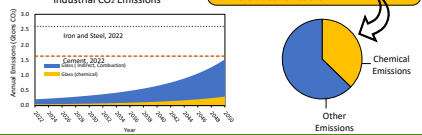
Decarbonizing PV Glass Manufacturing



- More than 2.5 billion panels to reach Solar Futures(1 TW **in USA** by 2035)
- 77 billion kilograms of glass required
- 1/3 of glass emissions are chemical
- Project to reach 2022 Cement by 2050

Glassmaking emissions can be from **combustion** or **chemistry**

Chemistry example:
$Na_2CO_3 + SiO_2 \rightarrow Na_2SiO_3 + CO_2$
- chemical reactions contribute 36% of overall CO_2 emissions



Acknowledgements

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the United States Department of Energy Office of Energy Efficiency and Renewable Energy Advanced Manufacturing Office now the Advanced Materials and Manufacturing Technologies and Industrial Efficiency and Decarbonization Offices. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.